Fish Adult Movement and Larval Dispersal:

Science to inform marine protected area design

DRAFT

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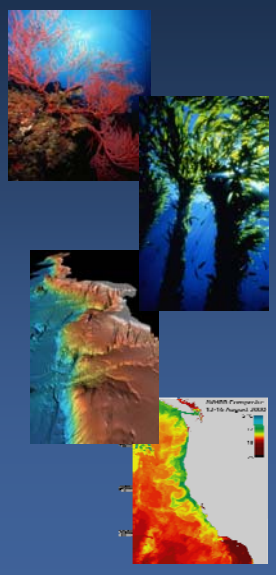
CA Marine Life Protection Act Goals

1. Protect **natural diversity** and **ecosystem functions**.
2. Sustain and restore marine life **populations**.
3. Improve recreational, educational, and study **opportunities**.
4. Protect representative and unique **habitats**.
5. Clear objectives, effective management, adequate enforcement, sound science.
6. Ensure that marine protected areas are designed and managed as a **network**.



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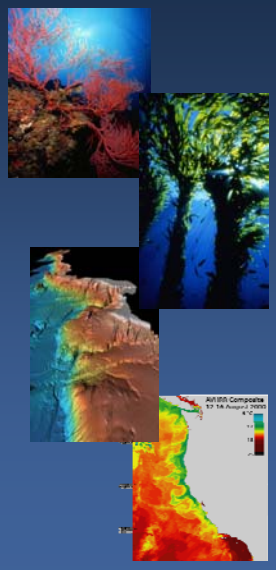
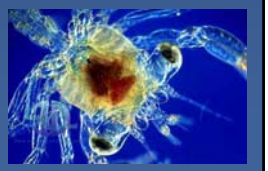


Protecting Populations

size and spacing

- MPAs must be large enough that adults don't move out of them and become vulnerable to fishing

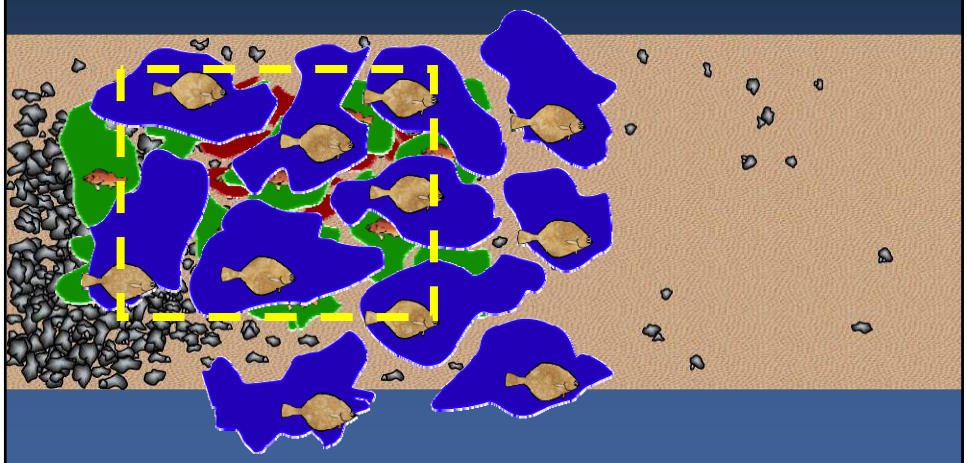
- MPAs must be close enough together that larvae can move from one to the next



How Does Movement Determine MPA Size and Shape?

- Population protection scales with movement and MPA size
- Movement affects the amount of spillover from an MPA (pros and cons)
- MPAs need to protect all the habitats that fish (and invertebrates) use over their lifetime

Population Protection Scales With Home Range and MPA Size



How Do We Know About Adult Movements?

Fishing, Direct Observation, Acoustics, Tagging,
Genetics, Current and Habitat Associations

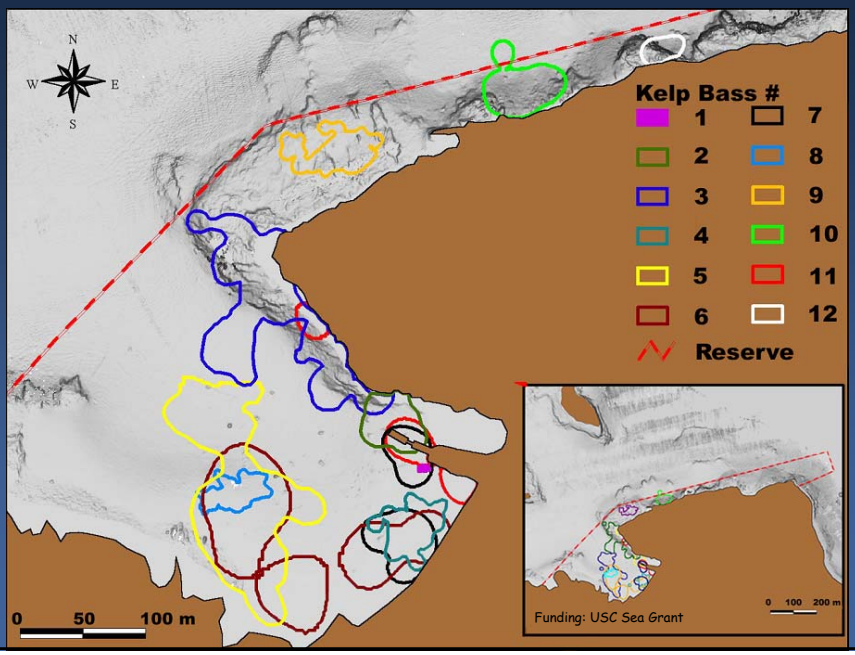


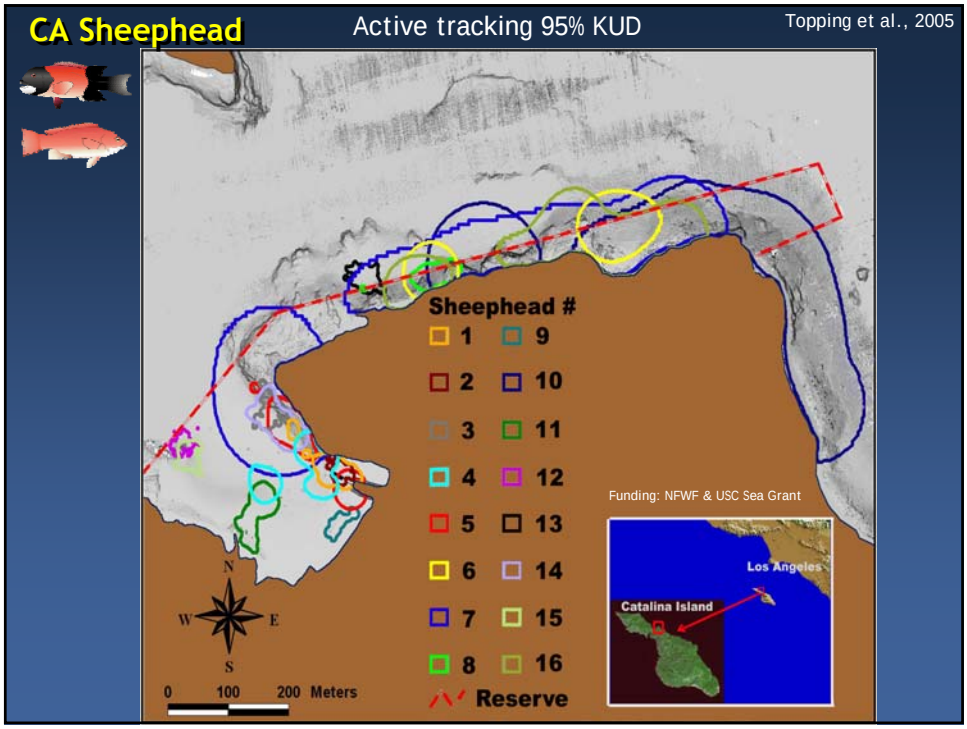


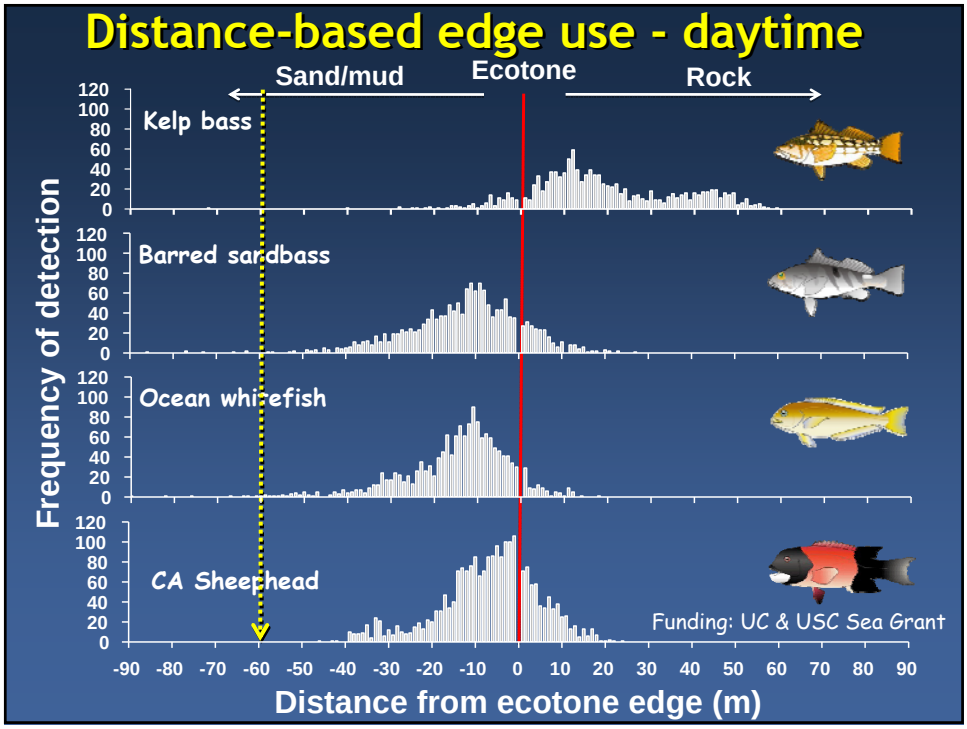

Kelp Bass

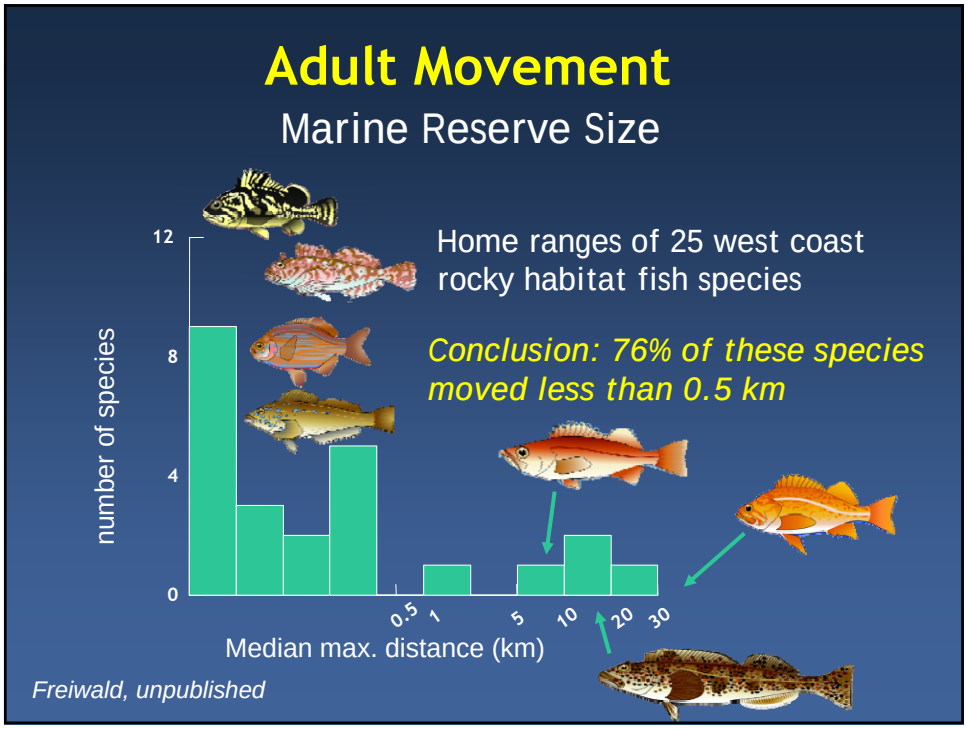
Active tracking
95% KUD

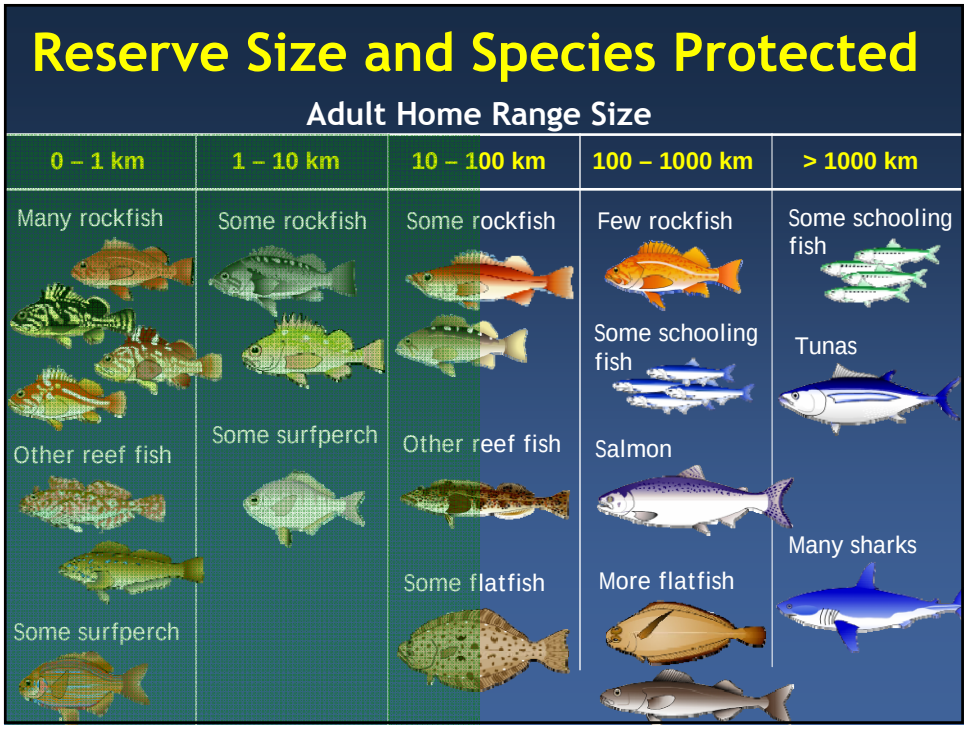
Lowe et al. 2003



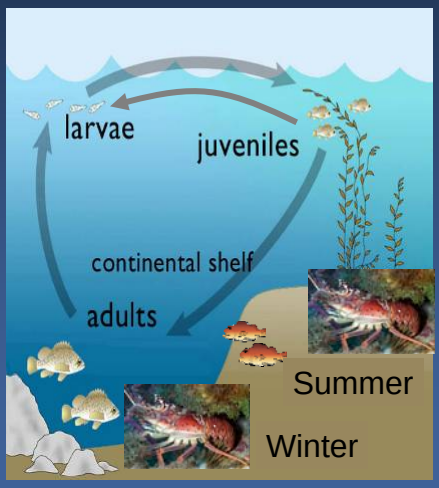

CA Sheephead
Active tracking 95% KUD
Topping et al., 2005
Sheephead #
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Reserve
N
W
E
S
0
100
200 Meters
Funding: NFWF & USC Sea Grant
Los Angeles
Catalina Island


Distance-based edge use - daytime
Sand/mud
Ecotone
Rock
Kelp bass
Barred sandbass
Ocean whitefish
CA Sheephead
Frequency of detection
0
20
40
60
80
100
120
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Distance from ecotone edge (m)
Funding: UC & USC Sea Grant


Adult Movement
Marine Reserve Size
Home ranges of 25 west coast rocky habitat fish species
Conclusion: 76% of these species moved less than 0.5 km
number of species
12
8
4
0
0.5
1
5
10
20
30
Median max. distance (km)
Freiwald, unpublished


Reserve Size and Species Protected
Adult Home Range Size
0 – 1 km
1 – 10 km
10 – 100 km
100 – 1000 km
> 1000 km
Many rockfish
Other reef fish
Some surfperch
Some rockfish
Some surfperch
Some rockfish
Other reef fish
Some flatfish
Few rockfish
Some schooling fish
Salmon
More flatfish
Some schooling fish
Tunas
Many sharks

Species Use Different Depths at Different Times



Protect the range of depths species use

Over their lifetime

Seasonally

Master Plan Size Guidelines

- Minimum alongshore span of **5 – 10 kilometers** (3 – 6 miles)
- Preferably **10 – 20 kilometers** (6 – 12 miles)
- Extend from the intertidal zone to deep waters (3 miles offshore)

Protecting Populations

size and spacing

- MPAs must be large enough that adults don't move out of them and become vulnerable to fishing

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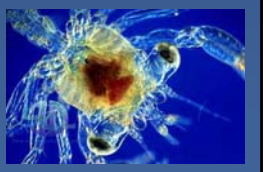
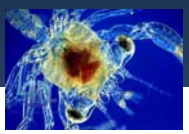
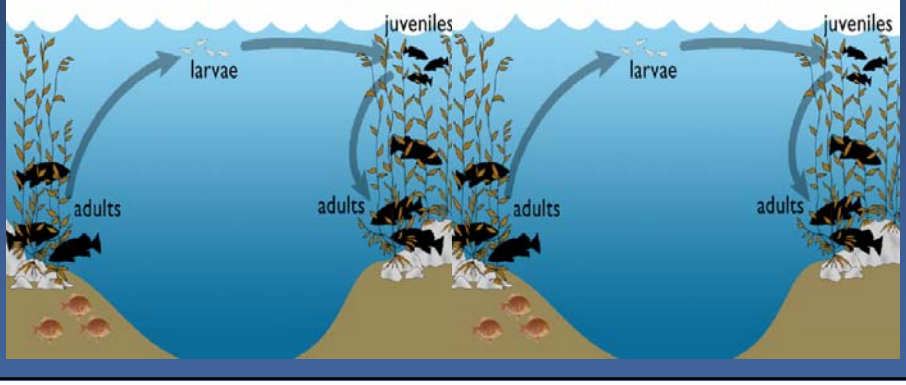
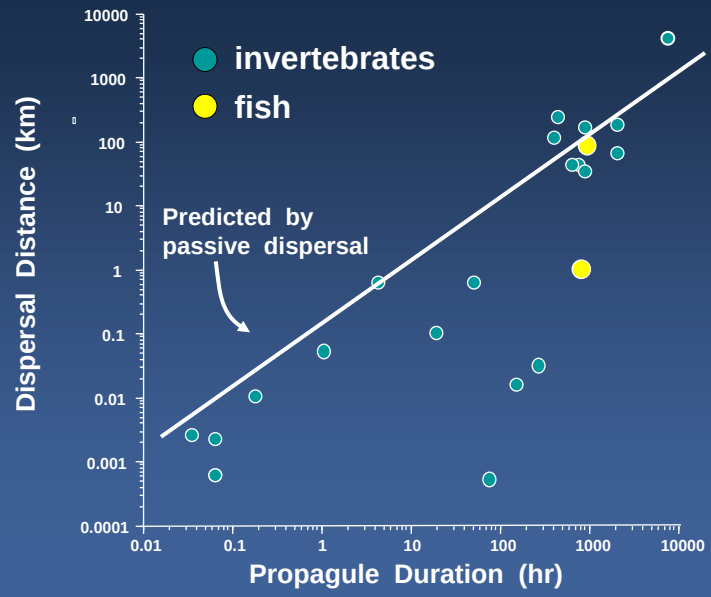


Reserves Connected by Larval Dispersal





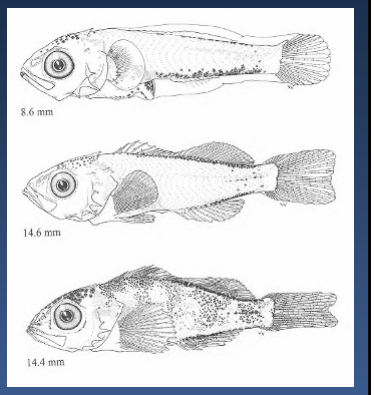
Pelagic Duration: a proxy for dispersal potential

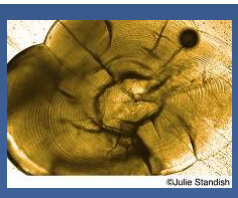


Shanks et al. 2003 Ecological Applications

Time in the Larval Stage (fish)

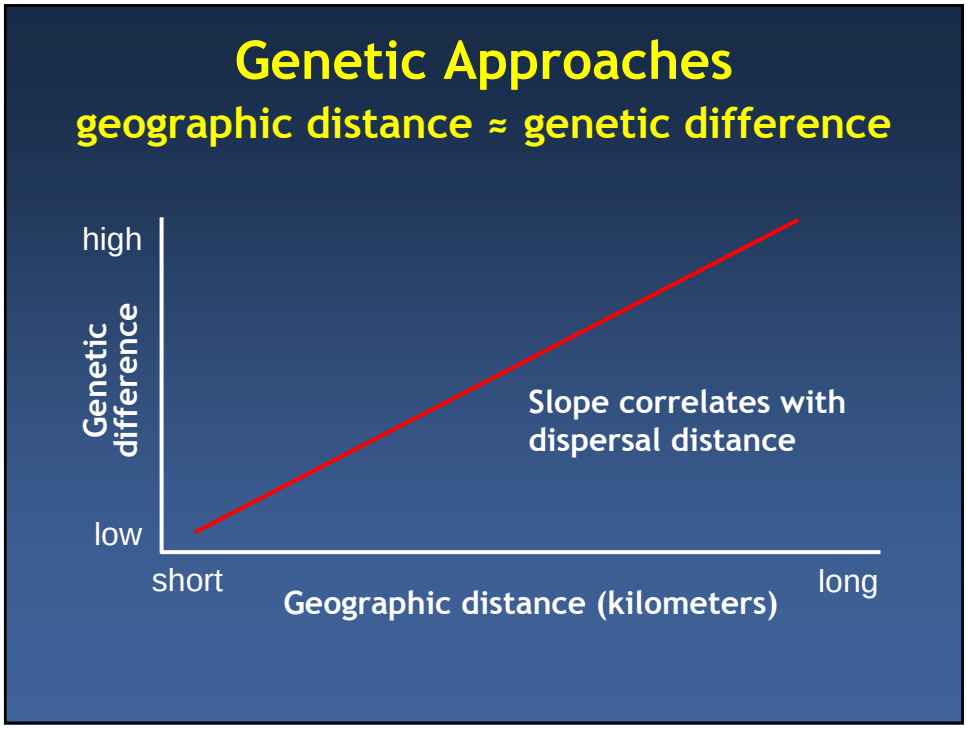
Western North American Coastal Fish	Time in Larval Stage midpoint (range)
Aurora Rockfish (*Sebastes aurora*)	105 (90-120)
Gopher Rockfish (*S. carnatus*)	75 (60-90)
Yellowtail Rockfish (*S. flavidus*)	85 (60-110)
Black Rockfish (*S. melanops*)	145 (110-180)
Blackgill Rockfish (*S. melanostomus*)	105
Blue Rockfish (*S. mystinus*)	105 (80-130)
Bocaccio (*S. paucispinis*)	160 (150 to 170)
Olive Rockfish (*S. serranoides*)	135 (90-180)
Kelp Bass (*Paralabrax clathratus*)	30 (25-35)
Spotted Sand Bass (*P. maculatofasciatus*)	22 (17-27)
White Seabass (*Atractoscion nobilis*)	32 (29-35)
Halfmoon (*Medialuna californiensis*)	60
Blacksmith (*Chromis punctipinnis*)	35 (32-38)
Garibaldi (*Hypsypops rubicunda*)	20 (18-22)
Rock Wrasse (Halichoeres semicinctus)	30 (26-34)
Senorita (*Oxyjulis californica*)	39 (36-43)
California Sheephead (*Semicossyphus pulcher*)	37 (34-52)
Giant Kelpfish (*Heterostichus rostratus*)	37 (14-60)
Blackeye Goby (*Coryphopterus nicholsi*)	70
Bluebanded Goby (*Lythrypnus dalli*)	70
California Halibut (*Paralichthys californicus*)	27
Pacific Sanddab (Citharichthys sordidus)	271
Speckled Sanddab (*C. stigmaeus*)	219 (113-219)
Petrale Sole (*Eopsetta jordani*)	180

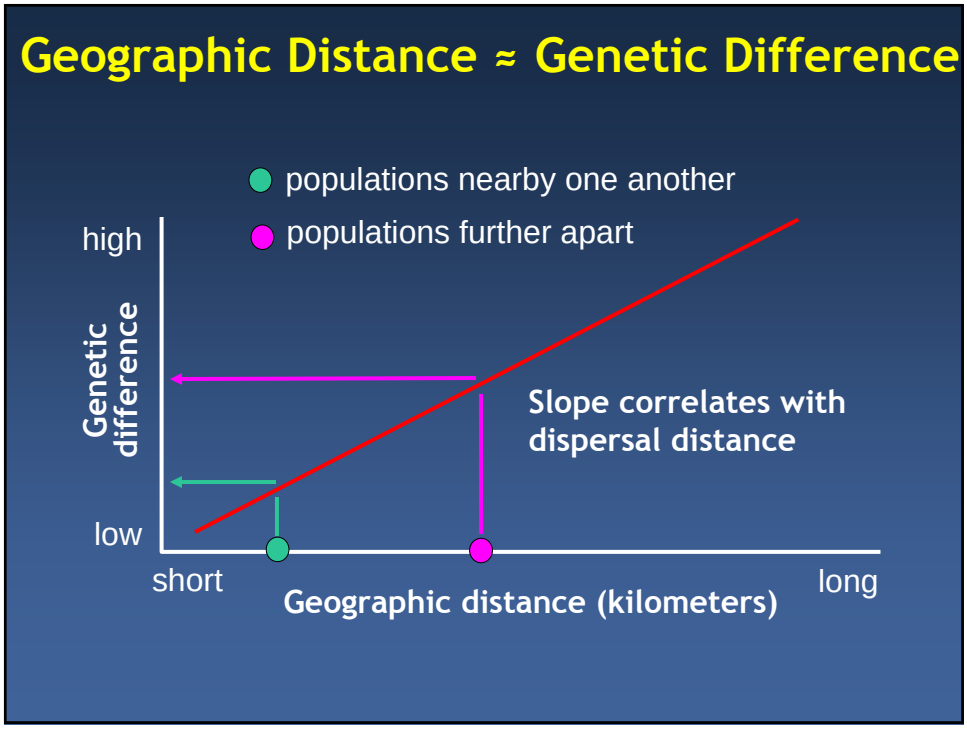


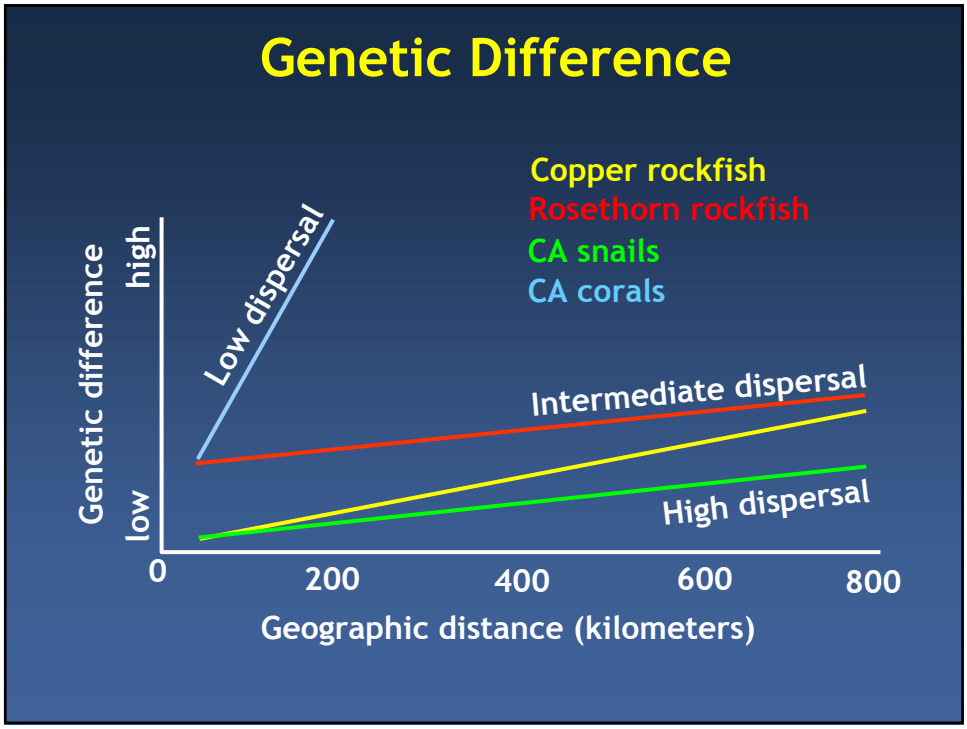


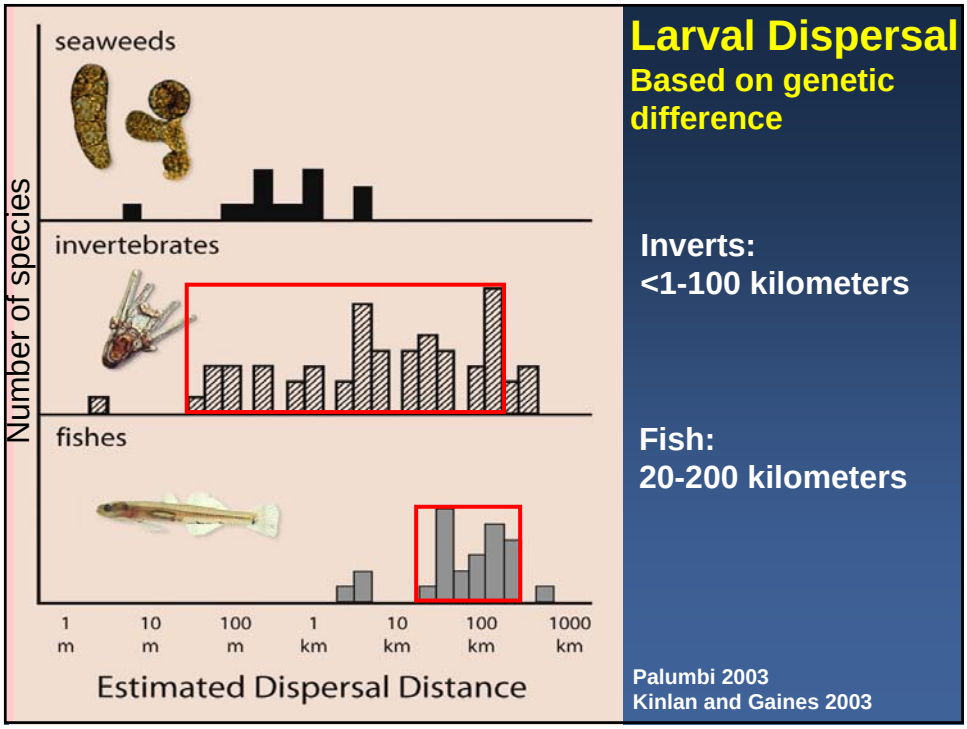
AVERAGE = 94 days

Shanks et al. 2003


Genetic Approaches
geographic distance ≈ genetic difference
high
Genetic difference
low
Slope correlates with dispersal distance
short
long
Geographic distance (kilometers)

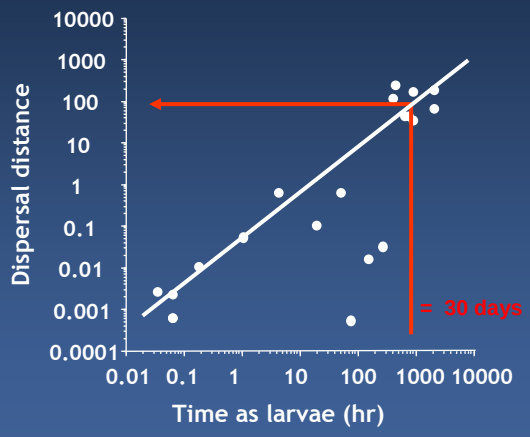

Geographic Distance ≈ Genetic Difference
populations nearby one another
populations further apart
high
Genetic difference
low
Slope correlates with dispersal distance
short
long
Geographic distance (kilometers)


Genetic Difference
Copper rockfish
Rosethorn rockfish
CA snails
CA corals
Genetic difference
high
low
Low dispersal
Intermediate dispersal
High dispersal
0
200
400
600
800
Geographic distance (kilometers)

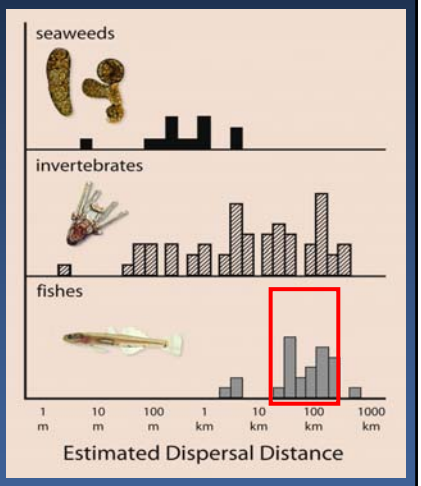

seaweeds
invertebrates
fishes
Number of species
1 m
10 m
100 m
1 km
10 km
100 km
1000 km
Estimated Dispersal Distance
Larval Dispersal
Based on genetic difference
Inverts:
<1-100 kilometers
Fish:
20-200 kilometers
Palumbi 2003
Kinlan and Gaines 2003

Different Estimates, Similar Results

Time in larval stage

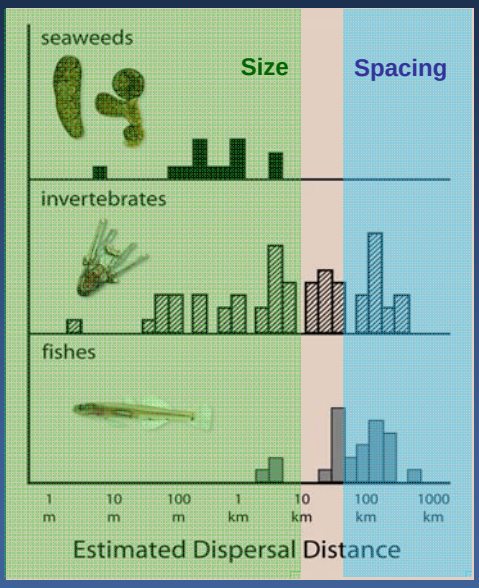


Genetic distance



Dispersal distance of invert larvae = 1 - 100 km
Dispersal distance of fish larvae = 20 - 200 km

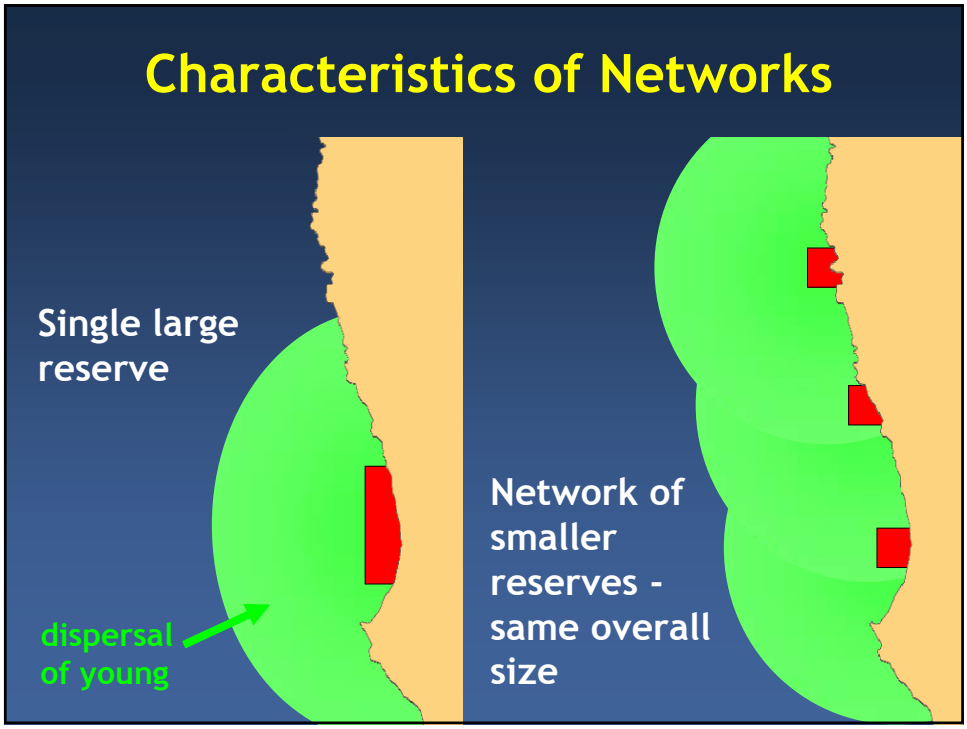
Size and Spacing Guidelines



- **Size:**
  - 5-10 km, minimum
  - 10-20 km, preferred
  - Intertidal to deep waters
- **Spacing:**
  - 50 - 100 km apart
- **Size and spacing are inter-related**
  - smaller MPAs should be closer together
  - larger MPAs may be spaced farther apart

Data from Kinlan and Gaines 2003, PISCO 2007

Characteristics of Networks



Roles of Multiple, Connected MPAs

- Increase area over which larval export from MPAs is realized
- Reduce negative and increase beneficial impacts to local fisheries along the coast
- Enhance connectivity and replenishment among MPAs
- Reduce dependency of populations inside MPAs on replenishment by populations outside MPAs
- Buffer against local catastrophes (e.g., oil spill, storms)
- Encompass the diversity of habitats and associated species

Summary

- MPA size is largely determined by adult movement patterns
- MPA spacing is largely determined by larval dispersal distances
- Size and spacing are interrelated